VEGETATIVE COMMUNITY ANALYSIS OF BIOSOLIDS TEST PLOTS AFTER FIVE YEARS OF GROWTH

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ABSTRACT

The application of municipal biosolids during reclamation has been gaining acceptance in recent years. A series of reclamation test sites were established at the Bingham Canyon Mine in Utah during 1995 and 1996. These test sites were established on the tailings impoundment surface, on capped waste rock surfaces and on a gravel-borrow area. At each site, biosolids were applied to plots at rates of between 10 and 30 dry tons/acre, and control plots received identical treatments with the exception that biosolids were not applied. Vegetative community surveys were conducted at seven of these paired plots in the summer of 2001. After five to six years of growth, the biosolids plots generally contained a higher percent cover, ~75% of which was provided by volunteer weed species. On average, cheat grass (*Bromus tectorum*) alone accounted for over half of the total cover at the biosolids plots. The control plots, where biosolids were not applied, generally had less total cover, but weedy species accounted for less than 20% of the cover that was present. On average, the absolute cover provided by non-weedy species at the control plots was about twice as high as at the biosolids plots. The species diversity of non-weedy species at the control plots was also higher than at the biosolids plots. Forbs and woody shrubs were most common on the control plots. Most differences between biosolids and control plots were found to be statistically significant at a 0.05 significance level using an ANOVA analysis. The application of biosolids at these rates may favor the growth of weedy species and inhibit the establishment of favorable species. These study results suggest that depending upon the reclamation objectives, biosolids application may not always be beneficial, and that application rates of less than 10 tons/acre may be optimal at reclamation sites.

INTRODUCTION

The Bingham Canyon Mine is located in the Oquirrh Mountains near Salt Lake City, Utah. Several reclamation test sites were established at the mine in 1995 and 1996. These sites were designed to test the effect of biosolids (composted municipal sewage sludge) application during the reclamation of tailings, waste rock and gravel-pit surfaces. Biosolids have been used at many other reclamation sites because they can improve the physical and chemical characteristics of the soil and may act as a slow release fertilizer. The study area has a semi-arid climate and average annual precipitation varies between about 15 and 20 inches/year. The test plots are located between 4400 and 6200 feet above mean sea level.

At each of these test plots, biosolids were applied at rates that varied between zero and thirty dry tons/acre. The biosolids were usually disked into the surface soil before the sites were planted. Data collected from these sites after the first one to two growing seasons generally indicated that the plots where biosolids were applied had produced much more biomass than the

control plots that received no biosolids. In these early surveys, weedy species were not observed to dominate any of the test plots (Marrs, 1997b; McNearny, 1998).

During the summer of 2001, seven of these paired test plots were revisited and new vegetative community analyses were performed. Two of the paired test plots were located on the tailings impoundment embankment, three were located on top of sulfide-bearing waste rock surfaces and two were located on a gravel-borrow area.

METHODS

Test plots were selected for analysis if they met the following criteria: 1) documentation was available that detailed the treatments each plot received when it was established, 2) the plots were more than five years old, 3) the plots had not been disturbed since establishment, and 4) the location and boundaries of the plots could be confidently identified in the field.

Vegetation community analyses were performed at each test plot according to the relevÈ, or "sample stand" method (Barbour et al., 1987). Plant identification and nomenclature generally follows Welsh et al. (1993) while exotic species were identified from Whitson et al. (1992). Using the relevÈ method, variable-sized quadrats (sub-sites) were sampled at representative locations within each test plot area. The number of individual quadrats sampled at each test plot varied from one to five, depending upon the size of the plot. Each quadrat was sized to contain at least 90-95% of the dominant plant species identified within the community during the general site reconnaissance. Within each quadrat, three parameters were measured: the absolute % cover of each species present, the sociability of each plant species, and the vigor class of each plant species (Tables 1 through 3). Percent cover estimates were visually estimated within cover classes defined by the Braun-Blanquet cover scale (Mueller-Dombois and Ellenburg, 1974). The cover for each observed species was measured as a category (a number between zero and seven denoting 0-100% cover, respectively) rather than a precise number. An exact estimate of percent cover is thought to give a false sense of precision and cover estimates from multiple observers rarely agree. Although some precision is lost, categorical classification has good repeatability.

Species diversity was approximated with the number of species observed within each test plot. Even though simple diversity based on species counts can be undesirable because it fails to consider the relative abundance of the species present, in conjunction with the percent cover data, the relative abundance can be inferred.

The data from the relevÈ surveys were used to investigate the effects of biosolids application on the revegetation efforts. Percent cover, species diversity, and weed composition were compared between the biosolids and control plots. Weeds were identified by referencing the following three texts:

Noxious Weed Field Guide for Utah, J. Merritt, N.D. Belliston, and S.A. Dewey, 2000
Weeds of the West, T.D. Whitson et al., 1992
Common Weeds of the United States, USDA, 1971

Table 1.
Cover Classes of Braun-Blanquet

Class	Range of % Cover	Median
1	75-100	87.5
2	50-75	62.5
3	25-50	37.5
4	2-25	15.0
5	1-5	3
+	<1- 0.5	0.75
R*	Rare	*

* R=Individuals occurring seldom or only once; cover ignored and assumed to be insignificant. SOURCE: Mueller-Dombois and Ellenburg 1974

Table 2.
Sociability Scale of Braun-Blanquet

Value	Meaning
5	Growing in large, almost pure stands
4	Growing in small colonies or carpets
3	Forming small patches or cushions
2	Forming small but dense clumps
1	Growing singly

SOURCE: Barbour et al. 1987

Table 3.
Vigor Class

Class	Meaning
E	Excellent
G	Good
F	Fair
P	Poor

In general, weedy species that were observed on the test plots were not part of the reclamation seed mixes that were applied. In most cases the weeds are volunteers on the plots. However, four species that are listed as weeds in one or more of these texts were included in some of the seed mixes applied to the test plots. Rubber Rabbitbrush (*Chrysothamnus nauseousus*) is a dominant native species on undisturbed slopes of the Oquirrh Mountains and was included in some of the seed mixes. Yellow and White sweet clovers (*Melilotus officinalis* and *Melilotus albus*, respectively) and Orchard Grass (*Dactylis glomerata*) have also been historically included in revegetation seed mixes. During the analysis of weed content in the test plots, these four species were considered to be non-weedy because they were intentionally seeded onto many of the test plots.

Average Absolute Cover for each test plot was calculated by averaging the median-point of the Braun Blanquet cover classes for each species at each of the quadrats (sub-plots). These average absolute cover values for each species was totaled and reported as total absolute vegetative cover at each plot. The total absolute vegetative cover for any one plot can exceed 100% as there could be several layers of vegetation contributing to the total (grasses, forbs, shrubs).

PAIRED TEST PLOT RESULTS

Table 4 presents the 2001 survey results for each of the paired test plots. The results presented below characterize the vegetation cover at a single point in time five to six years after the plots were established. The character of the vegetation has likely changed since the initial surveys were conducted immediately after planting and it is anticipated that the character of the vegetation will continue to change in the future.

Table 4.
Comparison of Absolute Cover and Species Diversity between Paired Plots

Test Plot	Absolute Cover of Weed Species (%)		# of Weed Species Observed		Absolute Cover of Non-Weed Species (%)		# of Non-Weed Species Observed	
	BSA	NBS	BSA	NBS	BSA	NBS	BSA	NBS
01-04	88	21	2	2	0.2	90	1	5
01-05	54	41	2	2	46	64	2	3
01-06 Tailings Cap	92	6	4	3	0.4	16	2	2
01-06 Soil Cap	101	17	6	7	7	62	7	14
01-07	99	8	8	5	29	120	8	14
01-09 No Treatments	59	1.5	7	6	60	33	6	15
01-09 All Treatments	85	0.7	7	4	25	48	3	14

Note: BSA = Biosolid Application
NBS = No Biosolid Application

The results for the individual sites are detailed below.

Site 01-04

Site 01-04 is located on the east side of the tailings impoundment embankment at an elevation of approximately 4400 feet above mean sea level. This area corresponds to Test Plot 7, set up in 1996 as a demonstration project for biosolids application (McNearny, 1996). Biosolids were applied at rates of between 20 and 30 dry tons/acre to one set of plots and a series of control plots were also established where no biosolids were applied. All of the plots were then drill seeded. When the site was revisited in 2001, the plots that received biosolids were dominated by Cheatgrass (*Bromus tectorum*) (absolute cover equaled 88%). Non-weed species had an absolute cover of less than one percent on the biosolids plots. At the control plots that received no biosolids, the absolute cover provided by non-weedy species, predominantly Western Wheatgrass, Sheep Fescue and Tall Wheatgrass, was about 90%. Weedy species at the control plots had an absolute cover of 21%.

Site 01-05

Site 01-05 is located on the northwest side of the tailings impoundment embankment at an elevation of approximately 4400 feet above mean sea level. This area corresponds to Test Plot 1, set up in 1995 as a demonstration project for biosolids application (McNearny, 1996). At

the site, a series of plots were established where biosolids were applied at rates of 0, 10, 20 and 30 dry tons/acre. About 6 tons/acre of slaked lime was also added to all of the plots to raise the pH of the acidic soils that were present. All of the plots were drill seeded. The 2001 survey results show that the plots that received biosolids had an average absolute cover of 100%. About half of this cover was provided by Cheatgrass and the other half was provided by Tall Wheatgrass. The control plot that received no biosolids had an absolute cover of 41 % provided by weedy species and about 64 % provided by non-weed species, predominantly Tall Wheatgrass.

Site 01-06 Tailings Cap

Site 01-06 is located at an elevation of 6150 feet on the Eastside waste rock disposal area at the Bingham Canyon Mine. This area corresponds to the 6190 Test Plot, established by Kennecott Utah Copper in 1995 to test various waste rock caps with and without biosolids application (Marrs, 1997a). The waste rock beneath the cap material is acidic and will not support vegetation. Two sets of paired plots were compared at Site 01-06.

An 18-inch thick tailings cap was used with and without biosolids in one set of paired plots. The 2001 survey found that the tailings cap that received 30 tons/acre biosolids had an absolute cover of 92% provided by weedy species, predominantly Cheatgrass. Non-weedy species contributed less than one percent to the absolute cover. The tailings cap that received no biosolids had an absolute cover of 22%. The majority of the cover was provided by Sheep Fescue and Western Wheatgrass and about six percent of the cover was provided by weedy species.

Site 01-06 Soil Cap

A second set of paired plots at Site 01-06 was constructed with a manufactured soil composed of alluvial sediments mixed with pond sludge. One plot received an 18-inch thick cap without biosolids, and the other plot received a 2 to 12 inch cap with 30 dry tons/acre biosolids. Weedy species, predominantly Cheatgrass and Clasping Pepperweed, had an absolute cover of 101% on the biosolids plot in 2001. Non-weedy species, predominantly Four-wing Saltbush, had an absolute cover of seven percent. The plot that received no biosolids had an absolute cover of 17% provided by weedy species, predominantly Cheatgrass. Non-weedy species had an absolute cover of 62%. The most common non-weed species observed were Western Wheatgrass, Rubber Rabbitbrush, Utah Sweetvetch, Yellow Sweetclover and Four-wing Saltbush.

Site 01-07

Site 01-07 is located at an elevation of 6050 feet on a reclaimed portion of the Eastside waste rock disposal area at the Bingham Canyon Mine. The site is on an east-facing slope that was capped with 18 inches of mixed sludge and alluvium. In 1994 one half of the slope was drill seeded without biosolids application and in 1995 biosolids were applied at 30 tons/acre to the other half of the slope before it was drill seeded (Marrs, 1997a). The 2001 survey indicates that the portion of the slope that received biosolids had an absolute cover provided by weedy-species, predominantly Cheatgrass and Clasping Pepperweed, of 99%. Western Wheatgrass and Slender Wheatgrass were the dominant non-weed species providing 29% of the absolute cover. The

portion of the slope that did not receive biosolids had an absolute cover of 128%. Non-weedy species provided 120% of the absolute cover. The dominant species on this portion of the slope were Yellow Sweetclover, Western Wheatgrass, Palmer Penstemon, Utah Milkvetch and Slender Wheatgrass.

Site 01-09 No Treatments

Site 01-09 is in an old gravel borrow area located at an elevation of about 5400 feet above mean sea level at the foot of the Eastside waste rock disposal area. This site corresponds to the Triangle Borrow Test Plots established by Kennecott Utah Copper in 1996 (Marx and Cordell, 1996). At the Triangle Borrow area a series of plots were set up to test the effects of biosolids, mycorrhizae, seed coating gels and soil gels on plant establishment. Two sets of paired plots were compared at Site 01-09.

Biosolids were applied at 0, 15 and 20 tons/acre at one set of test plots. No other treatments were made before the plots were drill seeded. In 2001 when the site was revisited, the absolute cover on the biosolids plots was 119%. Weedy species, predominantly Cheatgrass and Tumble Mustard provided about half of the cover and Intermediate Wheatgrass provided the other half. Non-weedy species provided about 33% of the absolute cover on the control plot and weedy species provided about 2%. The dominant species on the control plot were Slender Wheatgrass and Utah Sweetvetch.

Site 01-09 All Treatments

The second set of paired test plots at Site 01-09 received treatments with mycorrhizae, seed coating gels and soil gels. Biosolids were then applied to the plots at rates of 0 and 15 tons/acre. The biosolids plot had an absolute cover of 110% in 2001. Weedy species, predominantly Cheatgrass provided about 85% of the absolute cover and non-weedy species provided 25%. The dominant non-weed species were Slender Wheatgrass, Intermediate Wheatgrass and Shadscale. Non-weed species had an absolute cover of 48% on the plot that did not receive biosolids and weedy species covered less than one percent. The dominant species on this plot were Big Sagebrush, Slender Wheatgrass, Shadscale, Lewis Blue Flax and California Poppy.

DISCUSSION

Figures 1 and 2 are graphs that average the percent absolute cover provided by each species observed in the seven paired plots. The control plots that were planted without biosolids had an average absolute cover of 76% in 2001. Non-weedy species provided 62% of this cover and weedy species provided 14%. A total of 30 non-weedy species and 11 weedy species were observed growing on the control plots. The dominant species that were observed in order of decreasing abundance were: Tall Wheatgrass, Cheatgrass, Yellow Sweetclover, Western Wheatgrass, Slender Wheatgrass, Sheep Fescue, Palmer's Penstemon, Utah Milkvetch, Utah Sweetvetch, Rubber Rabbitbrush, Big Sagebrush and Clasping Pepperweed. Generally, all of these species except Cheatgrass and Clasping Pepperweed were in the seed mixes that were originally applied to the test plots.

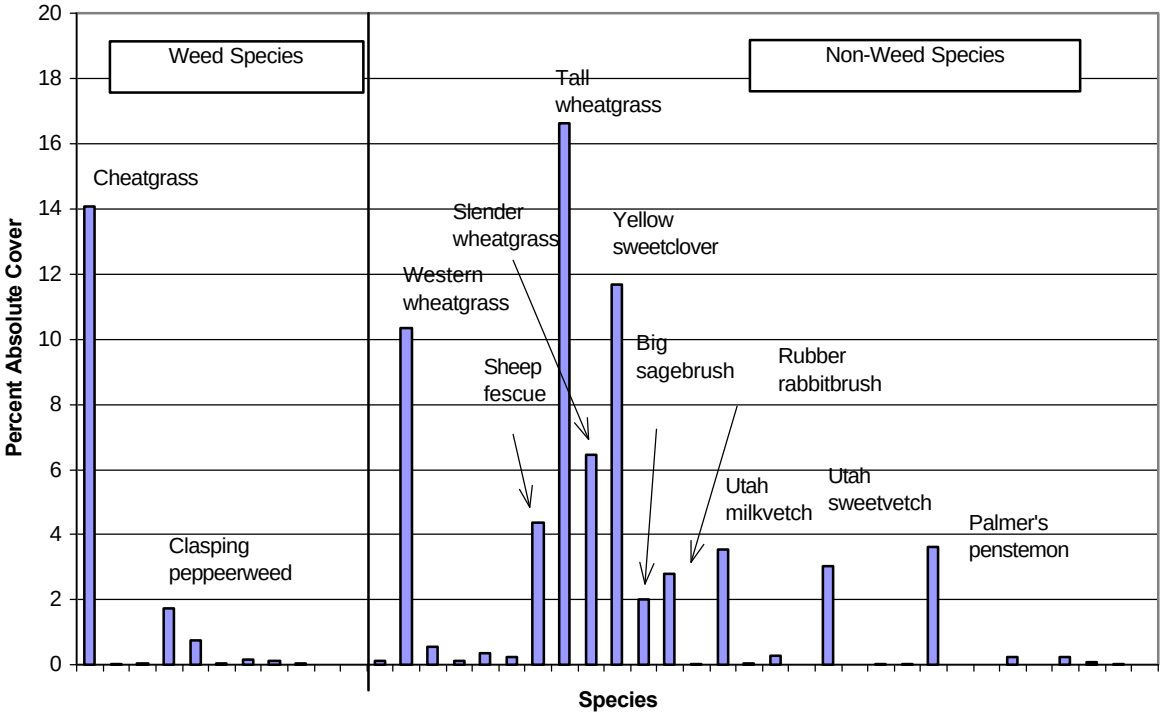

Figure 1. Average Absolute Cover by Species for Paired Plots with NO Biosolids Application

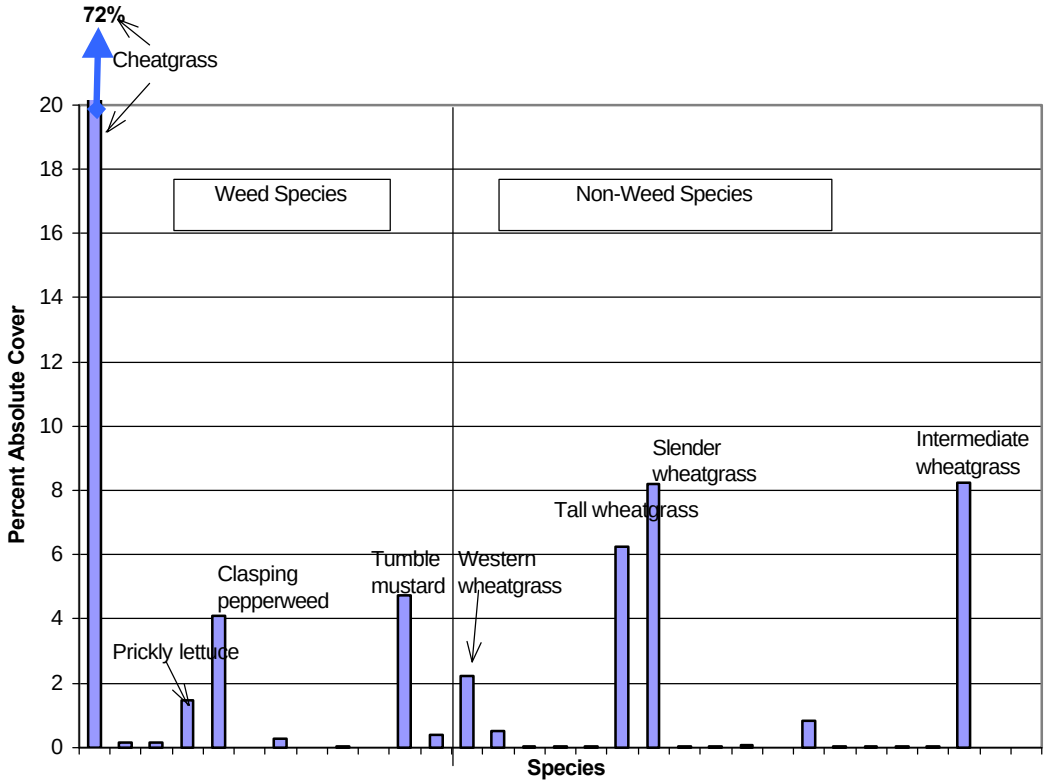

Figure 2. Average Absolute Cover by Species for Paired Plots with Biosolids Applied at 10 to 30 Dry Tons/Acre

During the 2001 field investigation, it was observed that the plots that were planted after biosolids were applied at rates of between 10 and 30 dry tons/acre had an average absolute cover of 107%. Non-weedy species provided 24% of this cover and weedy species provided 83%. A total of 19 non-weedy species and 12 weedy species were observed growing on the biosolids plots. On average, the absolute cover provided by Cheatgrass on the biosolids plots was 72%. No other species had an average absolute cover above 10%. Secondary species observed in order of decreasing abundance were: Slender Wheatgrass, Intermediate Wheatgrass, Tall Wheatgrass, Tumble Mustard, Clasping Pepperweed, Western Wheatgrass and Prickly Lettuce. Only the wheatgrass species were included in the original seed mixes that were applied to these sites.

In general the test plots that received biosolids had a higher total absolute cover than the control plots that received no biosolids. As shown on Figure 3, there is a weak positive correlation between the amount of biosolids applied to a plot and the absolute cover growing after five years ($R^2 = 0.20$). However, biosolids application appears to favor the establishment of weedy species on the test plots (Figure 4). There is a strong positive correlation between the biosolids application rate and the fraction of the total cover that is provided by weedy species ($R^2 = 0.85$). As shown on Figure 5, this results in a moderate negative correlation between the rate of biosolids application and the absolute cover provided by non-weed species ($R^2 = 0.40$). In most cases, the higher the biosolids application rate, the lower the absolute cover of the species that were intentionally seeded onto the site. On average, the control plots had more than twice as much cover provided by non-weed species than the plots that received 10 to 30 dry tons/acre biosolids. Species diversity, as measured by the number of species observed, was also higher on the control plots. An average of 9.2 species were observed on each of the biosolids test plots, but only 4.1 were non-weedy species. An average of 13.7 species were observed on each of the control plots, of which 9.6 were non-weed species.

An ANOVA analysis was performed on the seven paired plots for several of the measured parameters (Table 5). The differences in the absolute cover provided by non-weedy species was found to be statistically significant at a 0.05 significance level using an ANOVA analysis (p=0.03). The differences in total absolute cover provided by all species was also found to be statistically significant (p=0.05). However, total species diversity between plots that did and did not receive biosolids was not statistically significant at a 0.05 significance level (p=0.24).

Table 5.
Statistical Analysis of Differences between Treatments (Biosolids versus Non Biosolids) using an ANOVA analysis

Absolute Cover of Non-Weedy species Total Cover Identified for all Non-Weedy Species						
Treatment	Mean	St. Dev.	95% C.I.	F-value	d.f.	p-value
Biosolid	24	23	22	5.71	12	0.03
Non Biosolid	62	35	35			

Species Diversity Total Number of Species Identified						
Treatment	Mean	St. Dev.	95% C.I.	F-value	d.f.	p-value
Biosolid	9.2	5.7	5.3	1.53	12	0.24
Non Biosolid	13.7	8.0	7.4			

Total Absolute Cover Total Number of Species Identified						
Treatment	Mean	St. Dev.	95% C.I.	F-value	d.f.	p-value
Biosolid	107	12	11	4.41	12	0.05
Non Biosolid	76	40	37			

The application of biosolids at rates of between 10 and 30 dry/tons acre appears to favor the growth of volunteer weedy species at the expense of non-weed species. In most cases the application of biosolids ultimately inhibited the establishment of species that were intentionally seeded onto the test plots at the Bingham Canyon Mine. These study results suggest that depending upon specific reclamation goals, biosolids application may not always be beneficial, and that application rates of less than 10 dry tons/acre may be optimal at reclamation sites. Unfortunately, these study results cannot be used to estimate the optimum biosolids application rate between 0 and 10 dry tons/acre that may aid in initial vegetation establishment without favoring the dominance of weedy species in the longer term.

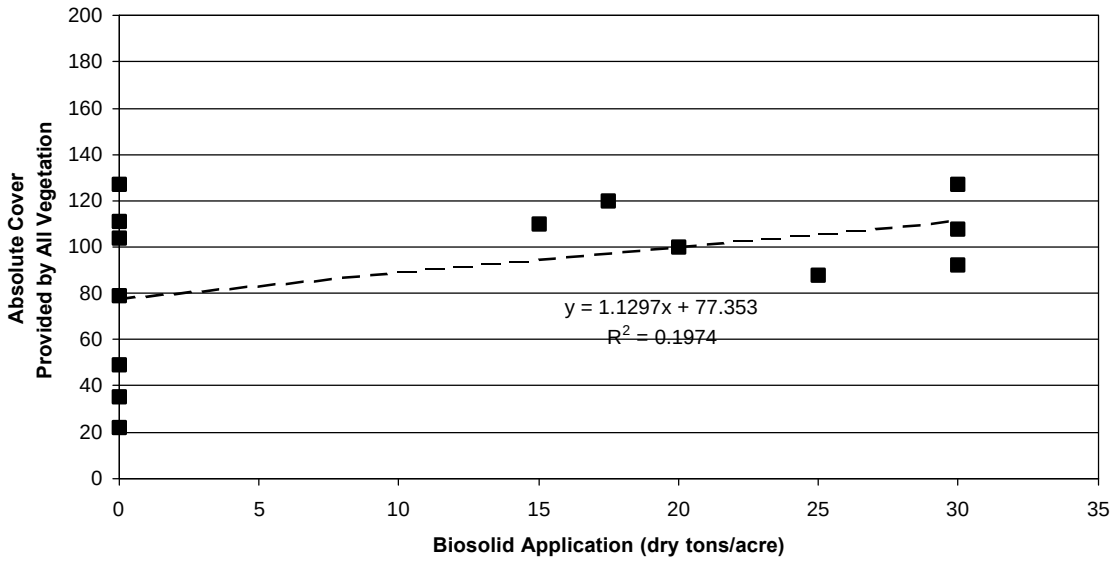

Figure 3. Absolute Cover Provided by All Species versus Tons of Biosolids Applied

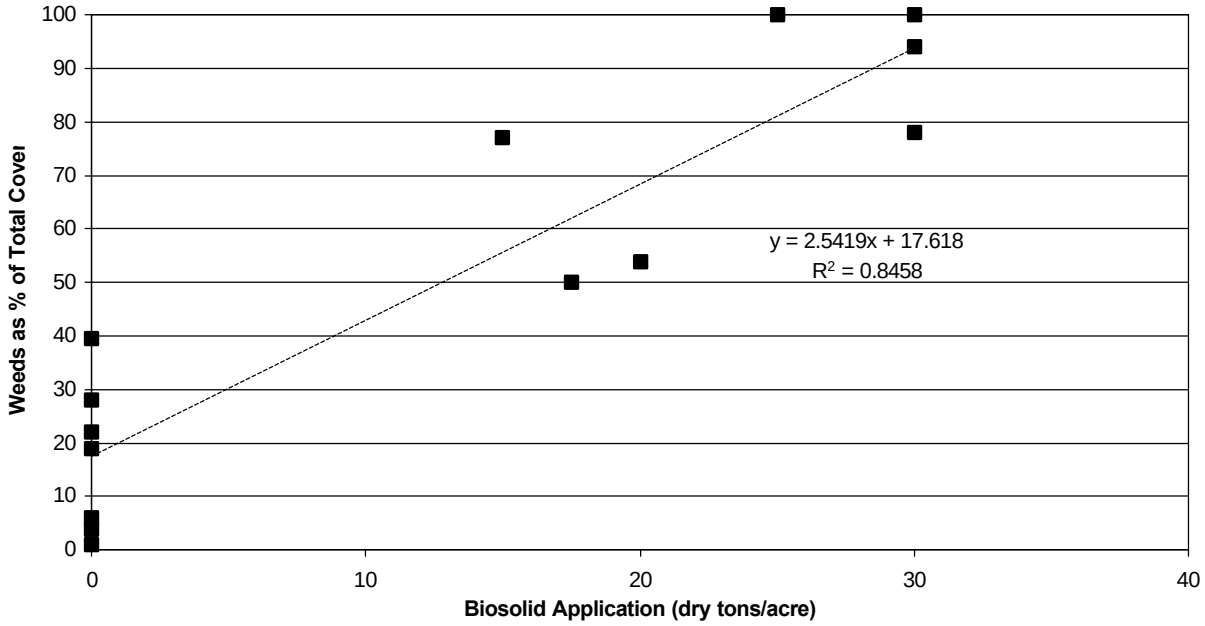

Figure 4. Percent of the Total Cover Provided by Weedy Species versus Tons of Biosolids Applied

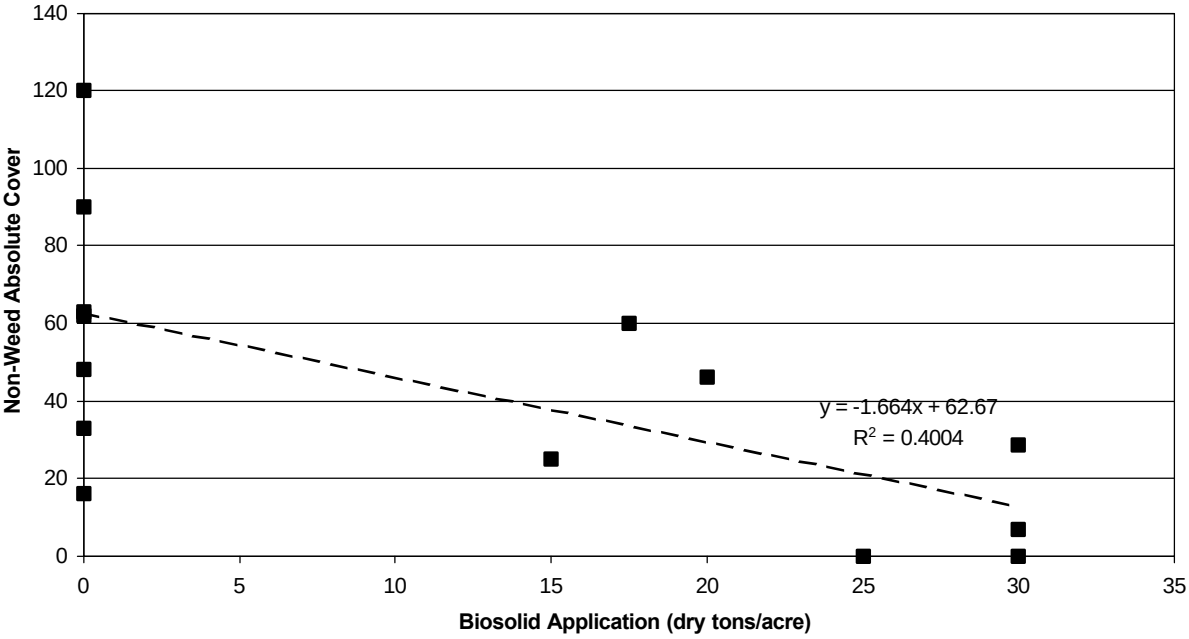

Figure 5. Absolute Cover Provided by Non-Weedy Species versus Tons of Biosolids Applied

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